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ULTRASOUND DIAGNOSTIC DEVICE
[CHOONPA SINDAN SOCHI]

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Claims

1. An ultrasound diagnostic device for visualizing a cross-sectional image of a subject using reflection of ultrasound, said ultrasound diagnostic device comprising:

a control circuit for electrically controlling the whole ultrasound diagnostic device;

a probe for transmitting ultrasound inside body of an subject placing on a surface of the subject and receiving the reflected ultrasound;

a transmitter circuit for outputting a transmitter signal to said probe;

an analog signal processing circuit to process a received signal received by said probe by analog signal processing; and

a scanning circuit to designate a scanning line position of said probe.

The ultrasound diagnostic device further comprises:

a decision circuit to determine if said probe is placed on a subject; and

a timing pulse generator to output periodic pulse to set the time point to periodically perform the determination;

wherein said decision circuit comprises:

a comparator to output a signal when an output signal of the analog signal processing circuit exceeds a certain intensity;

a time gate generation circuit to output a signal at the time point a certain length of time later than the time point of transmission while receiving the signal as an input signal;

a scanning line selection circuit to output a signal when the scanning line is at an appropriate position for said probe, while receiving a signal from said scanning circuit and a probe code signal from said probe to distinguish the probe as input signals;

an AND circuit to output a result of “AND” operation of three signals, output signals respectively from said comparator, said time gate generation circuit, and said scanning line selection circuit as the input signals; and

a hold circuit to hold an output signal of said AND circuit when there is a timing pulse signal while receiving an output signal of said AND circuit and an output signal of said timing pulse generator as the input signals and to output the holding state as the output signal.

In the ultrasound diagnostic device, a halt and start-up of operation of said scanning circuit and said transmitter circuit are controlled using an output signal

of said hold circuit as the input signal.

3. Detailed Description of the Invention

[Applicable Industrial Field]

The present invention relates to an ultrasound diagnostic device to visualize and medically diagnose a cross-sectional image of a subject, which varies in real time, by electrically treating and irradiating ultrasound onto a body of a subject such as a human body, and then receiving and processing reflection of the ultrasound inside the subject.

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[Conventional Technique]

In these years, an ultrasound diagnostic device has been widely used for examining an inner structure of an object using reflection of ultrasound or for diagnosing a biomembrane alive in real time. Among them, a scanning method, which is called “B-mode”, whereby a two-dimensional cross-sectional image is obtained, has been most widely used. In addition, “D-mode” whereby a blood flow signal can be obtained by the Doppler effect or “M-mode” to track change of a cross-section with time are also practically used.

In those methods, there are the following two methods for actually scanning ultrasound. One is an electron

scanning method, in which an ultrasound scanning line successively moves by electronically switching a number of oscillator arrays, and the other is a mechanical scanning method that forms a fan-shaped scanning region by swinging the oscillator with a motor. In these scanning methods, execution and halt of scanning are done by commands from a user with an operative board attached to the ultrasound diagnostic device. Hereunder, operation of the ultrasound diagnostic device will be fully described.

Fig. 10 is a block diagram of an ultrasound diagnostic device according to a conventional technique. In the figure, one probe [1] is used, and the probe [1] is electrically connected to a transmitter circuit [40] that generates a signal [102] to transmit ultrasound; an analog signal processing circuit [20] to receive the reflected signal from a subject and process the signal [101] by analog signal processing; a scanning circuit [45] to generate a signal [104] that two-dimensionally scans a scanning line for transmitting/receiving ultrasound; and a control circuit [71] to transmit a signal [103] that indicates a probe code to identify the type of the probe [1], respectively.

The analog signal processing circuit [20] includes a receiving circuit [21], a detector circuit [22], and a

logarithmic amplifier circuit [23], which are successively connected in series, and outputs an analog signal [108] while receiving the signal [101], which is a signal received from the probe [1], as the input signal.

Once a user sends commands to select desired operation or function using the operative board [75], a command signal is transmitted from the control circuit [71] to the whole system that composes the ultrasound diagnostic device, and thereby the whole system is controlled. The control circuit [71] recognizes a scanning method or frequency difference by reading the probe code signal [103] from the probe [1], and correspondingly controls the system. The control circuit [71] directs the transmitter circuit [40] to perform certain operation by sending a signal to the transmitter circuit [40], and simultaneously directs the device to mechanically or electronically scan a specific two-dimensional scanning region by operating the scanning circuit [45] according to the type of the probe [1]. The reflected signal from a subject is received by the probe [1]. The received signal [101] is received by the receiving circuit [21] as the input signal and then amplification and filtering processes are performed. Thereafter, the signal [108], which is detected by a detection circuit [22] and logarithmically amplified with

the logarithmic amplifier circuit [23], is converted from an analog signal to a digital signal by an A/D converter [30], and then stored in an image memory provided inside a digital scan converter, which is abbreviated as "DSC" [31]. Successively taking out and sending the signal in the image memory is to a TV monitor [32], a two-dimensional image is displayed on the TV monitor [32]. The series of operation is all controlled by the DSC [31]. The display magnification and the display depth of an image displayed on the TV monitor [32] are directed with the operative board [75], and transmitted to the DSC [31] through the control circuit [71].

[Problems to be Solved by the Invention]

In a conventional ultrasound diagnostic device of this type, a direction for sending ultrasound and scanning is given with a switch provided on the operative board [75]. An image forming device of this type is generally equipped with a switch to fix an obtained image for using upon recording an image, and the switch also works as a switch to transmit and to stop or start scanning. However, since a user uses this device while examining how a subject is doing, in the actual situation, the probe [1] is often off from a subject for very long time although the device is in the startup state. When the probe [1] is not placed on a

subject, it is not necessary to perform operations such as transmission, scanning, and reception of ultrasound. If the probe [1] is in the operated state regardless of whether the probe [1] is placed on a subject as described above, electricity is wasted and the life of the probe [1] is also shortened. The shorter life of the probe [1] may be caused by a problem such as deterioration of piezoelectric characteristics of a piezoelectric oscillator, but also by deterioration of an acoustic matching layer or the adhesive layer.

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In addition, in case of mechanical scanning, such problem could be caused by wear of a motor or heat/force transfer mechanism.

An object of the invention is to provide an ultrasound diagnostic device, whereby deterioration of the probe is delayed so as to extend the life and power consumption can be saved by automatically suspending operations such as transmission or scanning ultrasound when the probe is not placed on a subject.

[Means to Solve the Problems]

In order to solve the problems, according to the invention, there is provided an ultrasound diagnostic device that can visualize a cross-sectional image of a

subject using reflection of ultrasound, and includes a control circuit to electrically controlling the whole ultrasound diagnostic device; a probe to transmit ultrasound inside body of an subject placing on a surface of the subject and receive the reflected ultrasound; a transmitter circuit to output a transmitter signal to the probe; an analog signal processing circuit to process a signal received by the probe by analog signal processing; and a scanning circuit to designate a scanning line position. The ultrasound diagnostic device further comprises: a decision circuit to determine if the probe is placed on the subject; and a timing pulse generator to output periodic pulse to set the time point to periodically perform the determination, wherein the decision circuit comprises: a comparator to output a signal when the output signal of the analog signal processing circuit exceeds a certain intensity; a time gate generation circuit to output a signal at the time point a certain length later than the time point of transmission of a signal as the input signal; a scanning line selection circuit to output a signal from the scanning circuit and a probe code signal to distinguish a probe from the probe as input signal when the scanning line is in an appropriate scanning line position corresponding to the probe; an AND circuit to output a

result of “AND” operation of three signals, i.e. output signals respectively from the comparator, the time gate generation circuit, and the scanning line selection circuit as the input signals; and a hold circuit to hold the output signal of the AND circuit when there is a timing pulse signal while receiving an output signal of the AND circuit and output signal of the timing pulse generator as the input signals and to output the holding state as the output signal. In the ultrasound diagnostic device, a halt and start-up of operation of the scanning circuit and the transmitter circuit are controlled using output signal of the hold circuit as the input signal.

(Working Principles)

According to the configuration of the invention, the ultrasound diagnostic device equipped with a control circuit to electrically controlling the whole ultrasound diagnostic device; a probe to transmit ultrasound inside body of an subject placing on a surface of the subject and receive the reflected ultrasound; a transmitter circuit to output a transmitter signal to the probe; an analog signal processing circuit to process a signal received by the probe by analog signal processing; and a scanning circuit to designate a scanning line position includes a decision circuit to determine if the probe is placed on a subject;

and a timing pulse generator to output a periodic pulse to set the time point to periodically perform the determination, wherein the decision circuit comprises a comparator; a time gate generation circuit; a scanning line selection circuit; an AND circuit; and a hold circuit. Each configuration and operation are as described below.

Since a first wave of multiple reflection generated in the probe when the probe is not placed on a subject has much higher intensity than that of a reflected wave generated when the probe is placed on a subject, by outputting a signal from the comparator only when the output signal of the analog signal processing circuit exceeds a certain intensity using the difference in the intensity of the reflected wave while using the output signal of the analog signal processing circuit as the input signal, the signal are outputted only when the probe is not placed on a subject.

On the other hand, the time gate generation circuit outputs a pulse signal after a time interval between the time point of signal transmission from the transmitter circuit and the time point of receiving a first wave of the multiple reflection, while receiving a signal indicating the time point of signal transmission from the transmitter circuit. The scanning line selection circuit outputs a

signal when the scanning line position that varies for each probe is in an appropriate position, receiving the signal from the scanning circuit and the probe code signal to distinguish probes from a probe as the input signals. Receiving output signals from the three components, i.e. the comparator, the time gate generation circuit, and the scanning line selection circuit as the input signals, an output signal of the AND circuit is the first wave of multiple reflection, and the time point of transmission this time is the time point of transmission to the scanning line position appropriate for the probe.

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Receiving the output signal of the AND circuit and the output signal of the timing pulse generator as the input signal, the hold circuit holds the output signal of the AND circuit until the next timing pulse when there is an output signal of the timing pulse and also outputs the holding state as the output signal. The output signal of the hold circuit is to hold the output signal of the AND circuit according to the timing pulse period, so that it is possible to control a halt or startup of operations of the scanning circuit and the transmitter circuit according to the output signal of the AND circuit, while receiving the output signal as the input signal.

[Working Examples]

Hereunder, the present invention will be described referring to Working Examples. Fig. 1 is a block diagram of an ultrasound diagnostic device of a working example of the invention. In the figure, the same circuits as those in Fig. 10 are marked with the same reference numerals and detailed description will be omitted. A decision circuit [60] determines whether a probe [1] is placed on a subject, and according to the result, the probe [1] outputs a signal to direct a control circuit [7] to start up or halt. A signal necessary for this determination is a signal [107] that is an output signal from a analog signal processing circuit [20]; a signal [108] to indicate the operation status from the control circuit [7]; a signal [105] that is a transmission timing signal from a transmitter circuit [40]; a signal [106] that is a scanning signal from a scanning circuit [4]; and a signal [103] that indicates a probe code from the probe [1]. A timing pulse generator [51] outputs a signal [110] that is a periodic pulse generated at 0.1 to 1 sec intervals in order to set a time interval for the decision circuit [60] to repeatedly perform the determination operation.

If the decision circuit [60] recognizes that the probe [1] is not placed on a subject when a command from a user

of an operative board [75] is “Startup”, a scanning is turned into the halt state by the control circuit [70] by a signal [109], and then the control circuit [70] transmits a signal to halt the normal transmission state.

Fig. 2 is a block diagram illustrating a configuration of the decision circuit in a working example of the invention. In the figure, a signal [110] outputted from the timing pulse generator [51] provides a timing for the determination operation by the decision circuit [60]. As shown in Fig. 1, the signal [110] as the timing pulse is also sent to the control circuit [70], and drives the transmitter circuit [40]. A time gate generator [62] generates a signal [122] as a gate signal that is delayed for a time interval t_0 using the transmission timing signal as the start point. In addition, a comparator [61] compares a signal [107] that is an output signal of the analog signal processing circuit [20] with a threshold value, and outputs a signal [121] if the signal [107] is higher than the threshold value. Since setting of the threshold value of the comparator [61] and the retention time t_0 of the time gate generator [62] vary depending on the type of a probe, they are set by reading a probe code. The scanning line selection circuit [65] is a circuit that selects only necessary scanning line and outputs a signal

[123] only when a scanning line is in a desired scanning line position.

The signal [123] is necessary because of the following reasons.

An ultrasound diagnostic device has several operation states, and whether it is appropriate to perform the determination operation at the scanning line position depends on the operation state. More specifically, when B-mode scanning (two-dimensional scanning) is performed, it is appropriate to perform the determination operation at a scanning position near the center in a scanning region regardless of whether a mechanical scanning method or an electron scanning method is employed. This is because edges of the scanning region may not contact with a subject in some cases, so that it is most secure to determine near the center if the probe is placed on a subject. In addition, in case of D-mode scanning or M-mode scanning, where the scanning position is fixed at a specific position, it is appropriate to perform the decision operation at the specified position. The fixed position is designated by a user using a trackball on the operative board. As described above, since a scanning line to determine if the probe [1] is placed on a subject may be different depending on the scanning method, the signal

[123] is necessary for selecting an appropriate scanning line that varies depending on a scanning method as described above.

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The AND circuit [66] outputs a signal [124] only when the signals [121], [122], and [123] are all high, and the hold circuit [67] holds the signal [124]. The hold circuit [67] performs the operation synchronizing with the signal [110] as the timing pulse from the timing pulse generator [51]. When the signal [124] is “Low”, the hold circuit [67] can switch from “High” to “Low”. The change like this is also made by synchronizing with the signal [110]. The hold circuit [67] outputs the holding state as the signal [109].

In Fig. 1, if the control circuit [7] receives the signal [109] and the signal [109] is “High”, the control circuit [7] suspends the B-mode scanning and also suspends the normal transmission. If the signal [109] is “Low”, the normal operation state is recovered by the control circuit [7]. This decision operation is repeated every about 0.1 to 1 sec. While it is more difficult to use if the interval is longer than 1 sec. since the response is slow, it is not necessary to perform the determination operation if the interval is shorter than 0.1 sec. Therefore, the

above range is appropriate for practical use.

Hereunder, working principle of the invention will be described.

Fig. 3 is a cross-sectional view of a mechanical scanning type probe that is commonly used. An oscillator [15] of a probe [10] is placed in an inner solution [17] sealed in a window [16]. By reciprocally swinging the probe [10] with a driving mechanism [18], the probe scans in a fan-like shape. When the probe [10] is placed on a subject, ultrasound from the oscillator [15] enters the subject through the window [16] as indicated with Arrow B. On the other hand, when the probe [10] is not placed on a subject, the ultrasound is substantially reflected at the window surface since the outer surface of the window [16] is air, and thereby multiple reflections A occurs between the oscillator [15] and a surface of the window [16] as illustrated in the figure.

Fig. 4 is a cross-sectional view showing an example of an electronic scanning type linear probe. This probe [11] includes a matching layer [13] and a lens layer [14] on a surface of the oscillator [12], and the outer surface of the lens layer [14] becomes a boundary face of the same multiple reflections as the outer surface of the window [16], and multiple reflections A occur as illustrated in

the figure.

Fig. 5 is a waveform diagram showing a change of signal waveform in the analog signal processing circuit [20] of Fig. 1. In this figure, the reflected signal (a) caught by the receiver circuit [21] becomes a signal (b) that is only in the positive side being detected by the detector circuit [22], and thereafter becomes a signal (C) having waveforms of compressed signal intensity being logarithmically amplified at the logarithmic amplifier [23].

Fig. 6 is a waveform diagram showing a signal [107] as an output signal of the analog signal processing circuit [20] when the probe is placed on a subject, and the reflected signal from a subject is received after t_0, time after ultrasound transmission, passed. If the distance between the oscillator [18] and the outer surface of the window [16] in Fig. 3, or the distance between the oscillator [12] and the outer surface of the lens layer [14] is l_0 and the sonic speed of the inner solution [17] is C<illegible>, the time interval t_0 is determined by $t_0=2l_0/$C<illegible>

Fig. 7 is a waveform diagram showing waveform of signal [107] when the probe is not placed on a subject. In this figure, the reflected signal A_1 is received from the

outer surface of the window [16] or the lens layer [14] at a position of time interval t_0, and then after a time interval t_0, A_2, A_3, and A_4 are received as multiple reflected signals. Since the reflected signal A_1 has much higher wave height than that of the reflected signal from a subject in Fig. 6, whether the probe 10 or the probe 11 is placed on a subject can be automatically determined by detecting the reflected signal A_1.

Fig. 8 is a time chart showing timing to perform the automatic determination. (a) is a signal [107], (b) is a signal [122], (c) shows a relation between a signal [107] and a threshold value set in the comparator [61], (d) is a signal [124]. In the period when the signal [107] exceeds the threshold value [130], the comparator [61] outputs a signal [121] as a pulse that corresponds to the period, and the signal [121], the signal [122], and the signal [123] as output signals of the scanning line selection circuit respectively become input signals of the AND circuit [66]. Accordingly, when all those three signals, [121], [122], and [123], are "High", the AND circuit [66] outputs a signal [124] shown in Fig. 8(d).

Fig. 9 is a waveform diagram showing relation between the signal [110] as the timing pulse and the signal [109] as the output signal of the hold circuit [67]. The pulse

width of the signal [110] is T_2, and the pulse interval is within range of 0.1 to 1 sec. as described above.

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Here, it is assumed that the probe placed on a subject is released therefrom in period T_2. Since there is no signal [124] for an output signal of the AND circuit [66] between the intervals T_1 and T_2, there is no signal [109], which is output signal of the hold circuit [67]. Since the probe is released from a subject in the middle of interval T_3, an intense reflected signal A_1 is generated in the first decision period T_R in the interval T_3, and an output signal is generated in the AND circuit [66], and the signal [124] is held by the hold circuit [67]. Then, whether the probe is placed on a subject is checked at the next timing pulse, i.e. initial decision interval T_R in interval T_4. Since the probe is still not placed on a subject in the example of this figure, the output signal [124] of the hold circuit [66] is still “High”.

As described above, by periodically determining when the probe is not placed on a subject by detecting multiple reflections of ultrasound, the operation state can be automatically set in the halt state. As a result, while the probe that is not actually in use is away from a subject, operations such as transmission of ultrasound or

scanning can be suspended and thereby effects of electricity saving and extended life of the probe can be achieved.

Here, the above description can be applied also in a device for diagnosing two-dimensional blood flow mapping on real time. In addition, needless to say, similar idea can be applied regardless of the type of the probe.

[Effects of the Invention]

As described above, the present invention is made by additionally including a decision circuit to determine whether the probe is placed on a subject; and a timing pulse generator to generate cyclic pulse to set timing for periodically performing the determination. The decision circuit includes a comparator, a time gate generator circuit, a scanning line selection circuit, and an AND circuit, and a hold circuit.

The first wave of multiple reflections generated in a probe when a probe is not placed on a subject has much stronger intensity in comparison with reflected wave generated when the probe is placed on a subject. The comparator outputs signal only when a probe is not placed on a subject by setting to output only when the output signal of the analog signal processing circuit exceeds certain intensity.

On the other hand, the time gate generator circuit outputs a pulse signal after a time interval between the time point of signal transmission from the transmitter circuit and the time point of receiving the first wave of the multiple reflections, while receiving the signal indicating the transmission time point from the transmitter circuit. In addition, the scanning line selection circuit outputs a signal when the scanning line position is in the appropriate position for determination, which is different among probes, while receiving a signal from a scanning circuit and a probe code signal to distinguish probe from the probe. Receiving output signals of the time gate generator circuit and the scanning line selection circuit and, an output signal of the comparator as the input signals of the AND circuit. The transmission time point at this time is the time point for transmitting to a scanning line position appropriate for the probe. Receiving the output signal of the AND circuit and the output signal of the timing pulse generator as the input signals, the hold circuit holds the output signal of the AND circuit until the next timing pulse when there is an output signal of timing pulse, and outputs the holding state as the output signal. The output signal of the hold circuit is for holding the output signal of the AND circuit according to

the timing pulse period, so that a halt or startup of operations of the scanning circuit and the transmitter circuit can be controlled according to the output signal of the AND circuit having the output signal as the input signal of the control circuit.

As described above, according to the invention, determining if the probe is not placed on a subject without any decision or operation by an user at all, the scanning circuit or the transmitter circuit are automatically suspended if the probe is placed on a subject, the scanning circuit or the transmitter circuit can be started. Accordingly, in addition to an excellent effect of eliminating unnecessary scan or transmission, there are effects of reduced power consumption and extended life of the probe. Furthermore, any additional operation or caution due to addition of a function would not be necessary.

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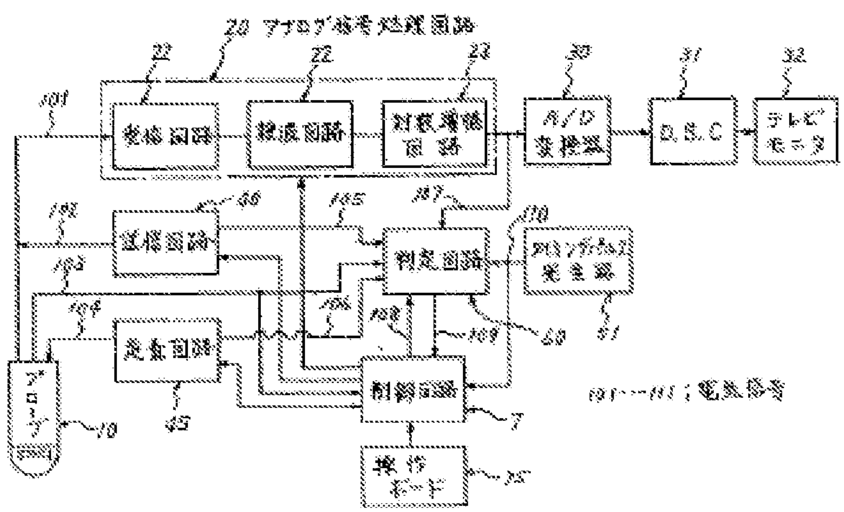
4. Brief Description of the Drawings

Fig. 1 is a block diagram showing a working example of the invention; Fig. 2 is a block diagram fully showing a part of Fig. 1; Fig. 3 is a cross-sectional view of a mechanical scanning type probe for explaining principle of the invention; Fig. 4 is a cross-sectional view of a linear

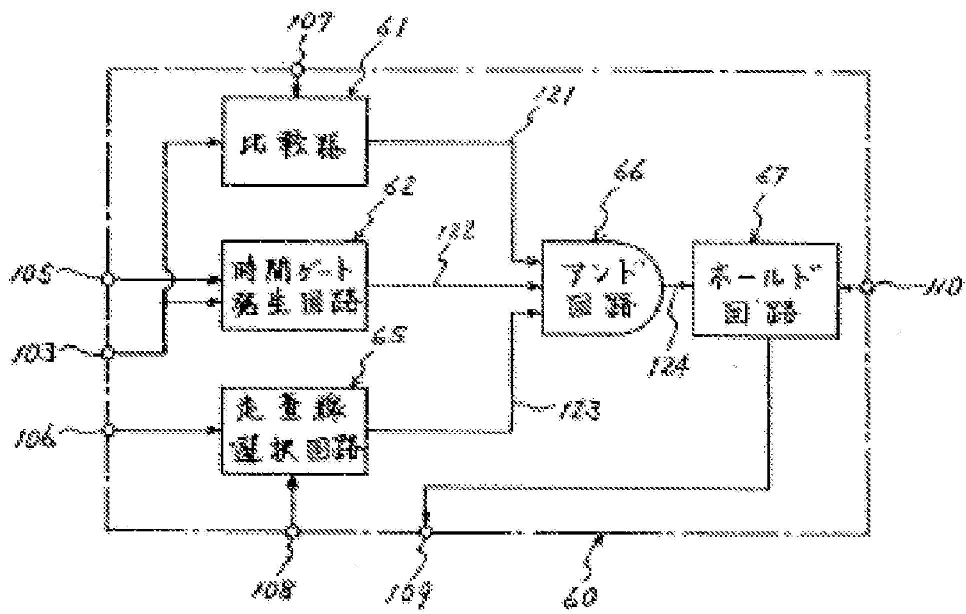
scanning type probe for explaining principle of the invention; Figs. 5, 6, and 7 are time charts for explaining principle of the invention; and Fig. 10 is a block diagram of a conventional technique.

1, 10, 11:	probe
20:	analog signal processing circuit
40:	transmitter circuit
45:	scanning circuit
51:	timing pulse generator
60:	decision circuit
61:	comparator
62:	time gate generator circuit
65:	scanning line selection circuit
66:	AND circuit
67:	hold circuit
7, 71:	control circuit



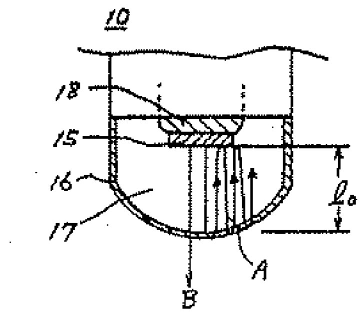
[FIG. 1]

7: control circuit
10: probe
20: analog signal processing circuit
22 (right): receiver circuit
22 (Left): detection circuit
23: logarithmic amplifier circuit
30: A/D converter
32: TV monitor
40: transmitter circuit
45: scanning circuit
51: timing pulse generator
60: decision circuit
75: operative board
100…111: electric signal



[FIG. 2]

61: comparator
62: time gate generator circuit
65: scanning line selection circuit
66: AND circuit
67: hold circuit



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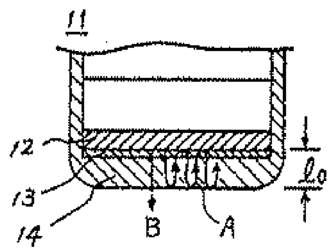
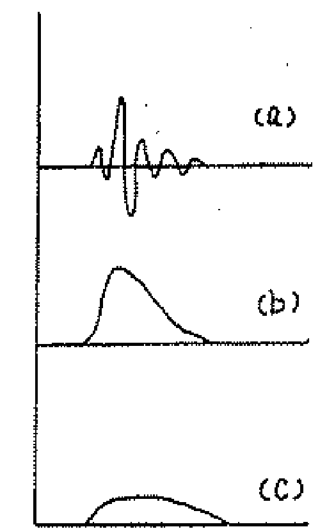
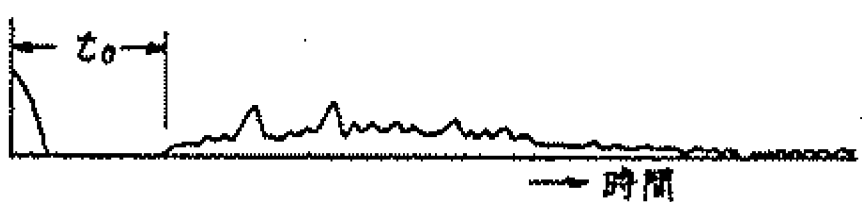


[FIG. 3]



[FIG. 5]



Time

[FIG. 6]

Time

[FIG. 7]

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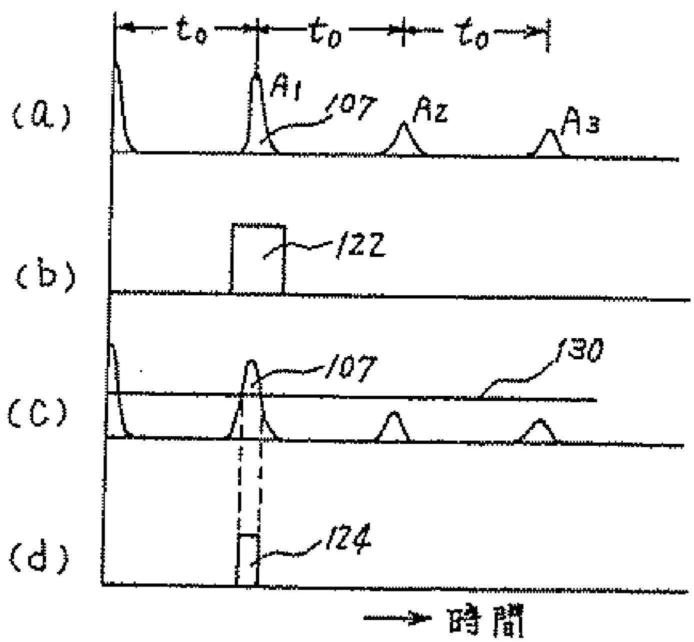
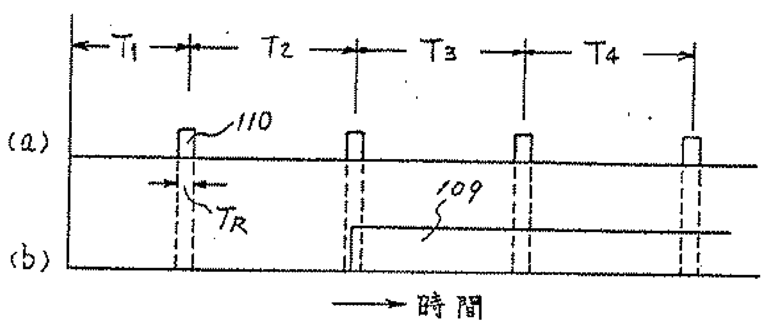


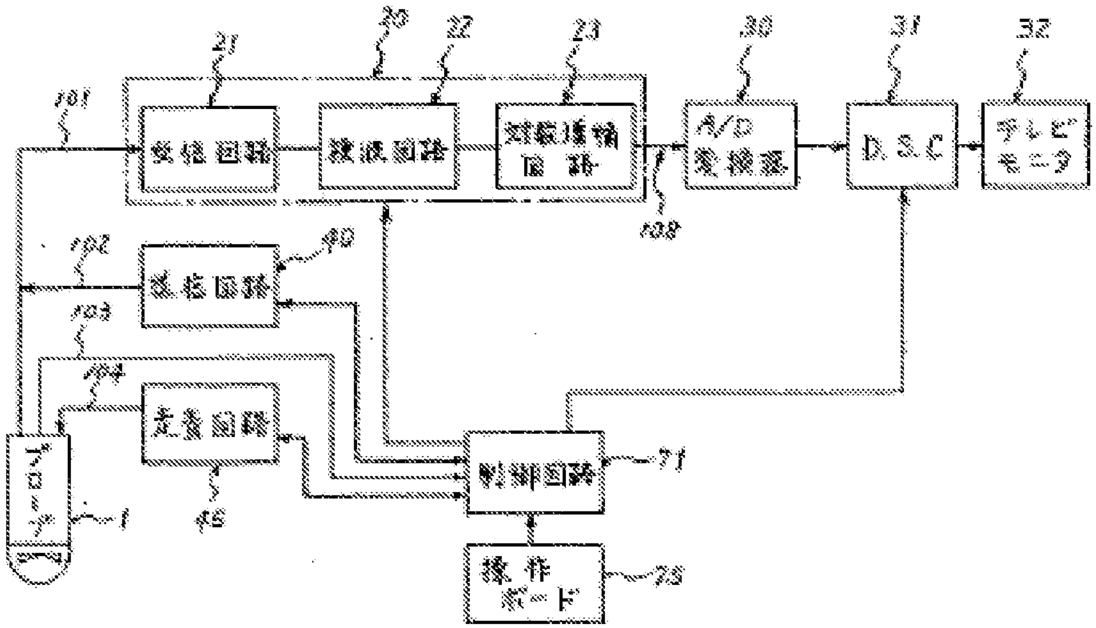
Time

[FIG. 8]



Time

[FIG. 9]



[FIG. 10]

1: probe
21: Receive circuit
22: detection circuit
23: logarithmic amplifier circuit
30: A/D converter
32: TV monitor
40: transmitter circuit
45: scanning circuit
71: control circuit
75: operative board